Red Hill Data Needs

Prioritization based upon Risk Management

Matt Becker, 25 Aug 2021

Key Risk Management Decisions
(based on Steve Linder presentation, April 3, 2021)

- Key Questions:
  - What infrastructure improvements are necessary at Red Hill to mitigate unacceptable threat to the water supply?
  - What monitoring needs to be in place to assure containment?
  - What mitigation strategies can be used to contain releases?

Key Risk Management Decisions
(based on Steve Linder presentation, April 3, 2021)

- Key Parameters:
  - Release Scenario
    - Timing: chronic or acute?
    - Magnitude: Near detection or catastrophic?
    - Material: Jet fuel, diesel?
    - Warning: detected or undetected at release source?
  - Points of potential exposure:
    - Red Hill Shaft
    - Halawa Shaft
    - Pearl Harbor

Data Gaps (after Linder)

- What is the data gap?
- Why is it critical?
- How will addressing the gap influence risk management decisions?
- What data are necessary to fill the gap?
- What is the likelihood that data and analysis can fill the gap?

What monitoring to assure containment?

- Information Needs:
  - Vertical and horizontal path of flow
    - RHS Pumping connectivity
    - RHS Not-pumping connectivity
    - Impact of recharge events/seasons
  - Velocity of transport
  - Attenuation during transport

What mitigation strategies can contain releases?

- Information Needs
  - Direction of shallow flow below tanks
  - Capture zone of RHS
  - First arrival time of contaminants at RHS
  - First arrival (if at all) at Halawa shaft
  - Travel time and attenuation to Pearl Harbor
  - Capture capacity of LNAPL below tanks

Direction of Flow below Tanks

Data Needs

- Mean (not local) velocity vectors
- Heads with sufficient accuracy: what potential surfaces can be fit within the error bars on the head measurements?
- Stratigraphic heterogeneity: are there discrete features with potentially different head gradients?

Candidate Measurements

- Highly constrained head measurements: acquired, but error bars not expressed
- Head profiles: flow meter or Westbay head gradient
- Borehole velocity vectors: recognizing they may deviate from the mean
- Velocity profiles: e.g. hydrogeophysical profiles or colloidal borescope

Capture Zones: Same data needs but under pumping and non-pumping conditions

Data Needs

- Mean (not local) velocity vectors
- Heads with sufficient accuracy: what potential surfaces can be fit within the error bars on the head measurements?
- Stratigraphic heterogeneity: are there discrete features with potentially different head gradients?

Candidate Measurements

- Highly constrained head measurements: acquired, but error bars not expressed
- Head profiles: equilibrated straddle packer head measurements
- Borehole velocity vectors: recognizing they may deviate from the mean
- Velocity profiles: hydrogeophysical or colloidal borescope e.g.

Earliest Arrival at RHS and Halawa

Data Needs

- Mean specific discharge between Red Hill and RHS/Halawa
- Effective porosity at transport scale
  - Stratigraphic heterogeneity
  - Connective heterogeneity (channeling)

Candidate Measurements

- Field scale tracer test between tanks and RHS
- Tracer tests only effective method for measuring transport at scale of interest
- Measurements are sensitivity to the distribution of injection

LNAPL Capture Capacity below Tanks

Data Needs

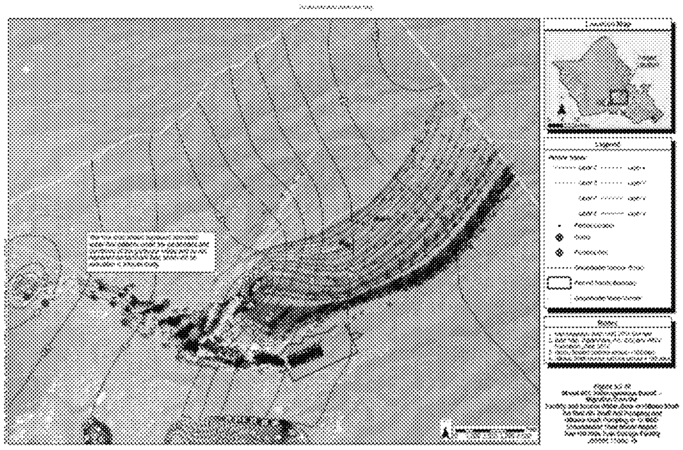
- LNAPL/water/air characteristic curves from fractured rock and clinker zones
- Relative permeability estimates for vertical and horizontal transport in bedrock

Candidate Measurements

- Geophysical (neutron and NMR) profiles to determine in-situ structure
- Laboratory estimates:
  - Lithologic porosity
  - Interstitial porosity
  - Wettability of weathered and un-weathered volcanics

Local vs. Regional

- Local measurements of hydraulics do not constrain problem at full scale of interest



Homogeneous vs. Heterogeneous

- Hydraulic gradient and flow vectors align only in isotropic permeability fields
- Heterogeneous permeability leads to deviations between regional and local flow
- Pumping/injection interacts with heterogeneous permeability to create unique hydraulic connections

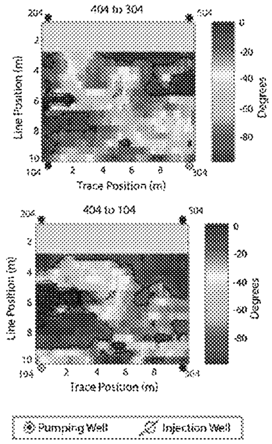
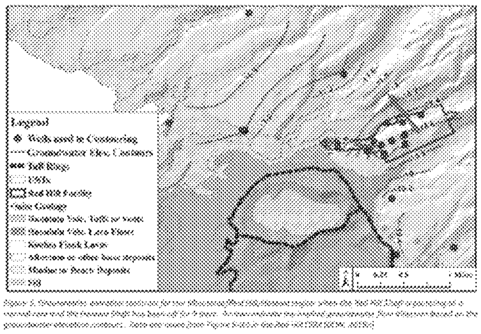


Fig. 3. Phase response of GPR signal reflected from the tested fracture. Phase change is inversely related to fluid salinity. Yellow and blue colors, therefore, indicate the presence of saline flow simulated between wells 404 and 304 (left) and 404 and 104 (right). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

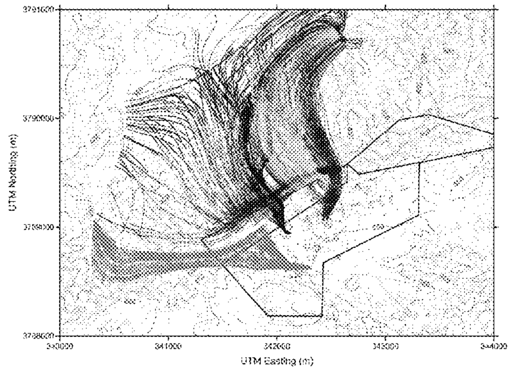
Tsoflias, G. P., C. Perll, M. Baker, and M. Becker (2014), Fracture Flow Channel Imaging Using Cross-Polarized GPR Signals, Fall American Geophysical Meeting. H52D-07.

Deterministic vs Probabilistic

Hand-Contoured Heads



Null Space Monte Carlo Particle Tracks (Scott James, Baylor U.)



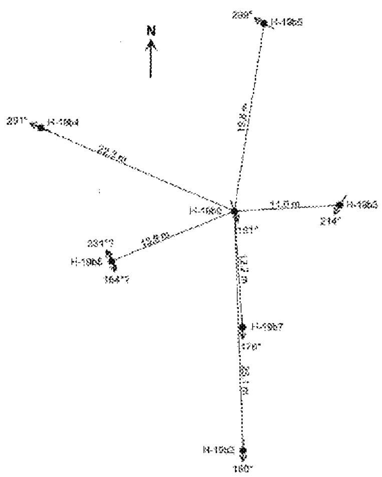


Figure 40 Mean flow directions in H-19 wells under ambient conditions.

Beauheim, R. L. (2000), Evaluation of the colloidal borescope as a monitoring tool at the waste isoation pilot plant site; SAND2000-2161;Rep., Sandia National Laboratories, Albuquerque.

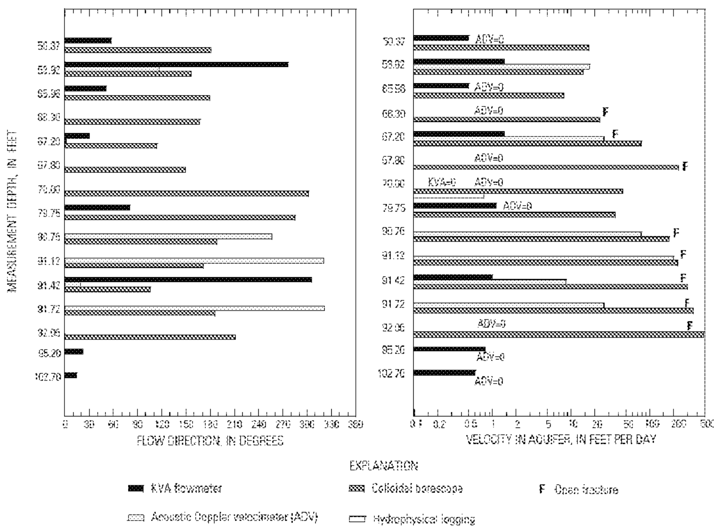


Figure 85. Flow directions and adjusted velocities for measurements made at selected depths in well FC-29, Fort Campbell, Kentucky.

Wilson, J. T., W. Mandell, F. Paillet, E. Bayless, R. T. Hanson, P. M. Kearl, W. B. Kerfoot, M. W. Newhouse, and W. H. Pedler (2001), An evaluation of borehole flowmeters used to measure horizontal ground-water flow in limestones of Indiana, Kentucky, and Tennessee, 1999, US Department of the Interior, US Geological Survey.

Measurement Interpretation Scenarios

- Result: colloidal borescope shows 30 degree change in flow direction from well to well
- Possible Interpretations:
  - This variability is within the measurement precision of the instrument
  - Flow system is compartmentalized
  - Flow system is horizontally heterogeneous
  - Flow system is stratigraphically heterogeneous
- Significance to Management Decisions
  - Direction of flow field?
  - Extent of capture zone?

Measurement Interpretation Scenarios

- Result: colloidal borescope shows 0 degree change in flow direction from pumping and non pumping conditions RHS
- Possible Interpretations:
  - This variability is within the measurement precision of the instrument
  - Well is not connected to RHS (contradicted by TFN)
  - Non-pumping and pumping flow vectors aligned
  - Flow system is stratigraphically heterogeneous and water underflows well
- Significance to Management Decisions
  - Direction of flow field?
  - Extent of capture zone?

Measurement Interpretation Scenarios

- Result: colloidal borescope shows 30 degree change in flow direction from pumping and non pumping conditions RHS
- Possible Interpretations:
  - This variability is within the measurement precision of the instrument
  - Well is hydraulically connected to RHS
- Significance to Management Decisions
  - Direction of flow field?
  - Extent of capture zone - yes